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Discussion of Hydrogeologic Data to Develop a Numerical Ground-Water-Flow Model of Mt. Desert Island, Maine

Administrative Report

U.S. Department of the Interior
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By Martha G. Nielsen

Administrative Report

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Contents

Figures

Tables

Conversion Factors

SI to Inch/Pound

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	.6214	mile (mi)
	Area	
hectare (ha)	2.471	acre
square km (km^2)	0.3861	square mi (mi^2)
	Hydraulic conductivity	
meter per day (m/d)	3.281	foot per day (ft/d)

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Altitude, as used in this report, refers to distance above the vertical datum.

Discussion of Hydrogeologic Data to Develop a Numerical Ground-Water-Flow Model of Mt. Desert Island, Maine

By Martha G. Nielsen

Abstract

Existing geologic and hydrologic data were compiled for the construction of a generalized ground-water-flow model of Mt. Desert Island for the National Park Service, Acadia National Park. This report discusses some of the limitations of those data for use in a model. A conceptual model of ground-water flow on Mt. Desert Island is discussed. Existing data on the hydrologic properties of the aquifer system are summarized. Suggestions are made for possible discretization of the hydrologic system for model development, boundary conditions, initial hydraulic conductivity values, stresses, and calibration targets. Finally, suggestions for additional data that would be necessary for completion of an island-wide model are discussed.

Introduction

The ecological health of many water resources in Acadia National Park on Mt. Desert Island, Maine, depends on ground-water recharge and the availability of clean ground water. Estuaries, lakes, and wetlands receive ground-water discharge from upland areas. The quality of the ground-water discharge is determined by the geology and land use between the recharge and discharge zones of the aquifer. Little is known at this time (2006) about ground-water movement on the island, and evaluating potential risks to important park water bodies is difficult without this knowledge.

In 2003, the U.S. Geological Survey and the National Park Service began a cooperative study to classify wetlands on Mt. Desert Island, Maine, and to evaluate ground-water movement with respect to wetland location (specifically, to evaluate ground-water discharge in and around large [greater than 2 ha] wetlands). The study was designed to assist natural-resource managers at the park by classifying wetlands according to their hydrologic function, degree of susceptibility to threats posed by degradation of ground-water aquifers on Mt. Desert Island, and by their susceptibility to changes in hydrology resulting from future climate change. (Nielsen and others, 2006; Nielsen, 2006)

As part of that study, existing data were compiled for the creation of a ground-water-flow model of the island, and the development and calibration of a generalized ground-water flow model was begun. This island-wide ground-water-flow model was intended as an aid to understanding recharge and discharge locations around the island. The finite-difference U.S. Geological Survey (USGS) MODFLOW-2000 model was used to simulate ground-water flow in the study area (McDonald and Harbaugh, 1988; Harbaugh and others, 2000). However, geologic complexities and

a lack of accurate information on hydraulic properties and anisotropy in the bedrock units prevented the model from being fully calibrated within the scope of the project. In addition, the central mountainous part of the island is composed of rocks of very low permeability that are difficult to model. A limited-area model of the island might be developed with existing data or using some additional data, and a full-island model could possibly be developed if enough new data were collected.

This report discusses a conceptual model of the ground-water-flow system, summarizes existing data that can be used in further development of a ground-water-flow model of Mt. Desert Island; discusses issues related to discretization of the ground-water-flow system, stresses, boundary conditions, and calibration targets; and provides suggestions for additional data that would be needed to more accurately construct and calibrate a ground-water-flow model for Mt. Desert Island.

Conceptual Model of the Ground-Water-Flow System

Ground water on Mt. Desert Island flows in two general geologic units: shallow, unconsolidated sediments left behind after the last glacial retreat, and the underlying fractured bedrock. The unconsolidated sediments are discontinuous, and range in thickness from 0 to about 30 meters (m) (Gilman and others, 1988; Caswell and Lanctot, 1977; and unpublished data of the Maine Geological Survey). Water in these sediments is transmitted through the coarser-grained units, such as till, end moraines, glacial-stream sediments, and coarse-grained emerged marine sediments (Gilman and others, 1988). A fine-grained unit, locally referred to as the Presumpscot Formation (Smith, 1985; Lowell, 1989), blankets much of the island, and acts to slow or prohibit the vertical movement of ground water. This unit may be found over, under, or incorporated within other unconsolidated sediments on the island. The average thickness of the surficial sediments on Mt. Desert Island is 3.3 m (on the basis of 560 unpublished ground-water well logs from the Maine Geological Survey). Wetlands are common on the island, especially in the north-central and southwestern parts (fig. 1), and have been mapped by the U.S. Fish and Wildlife Service (1998). This inventory map could be used to help simulate the wetlands on the island in the model.

Most private rural ground-water wells are drilled through the thin surficial sediments to the fractured bedrock below. The major bedrock units are mapped in Gilman and Chapman (1988) at a scale of 1:50,000. A 2002 study of ground-water availability in the town of Bar Harbor, Maine, analyzed the water-bearing capacity of the bedrock units on the island (Nielsen, 2002). The bedrock geology of Mt. Desert Island consists primarily of granitic and other igneous intrusions in the central area of the island, surrounded by a zone of contact metamorphism (referred to as the Shatter Zone in Gilman and others, 1988). Beyond this zone, which extends to the ocean on the northeast and southeast, are a group of metamorphosed layered volcanic rocks to the south, the Cranberry Island Volcanics (including some interbedded siltstones and slates); a gabbro-diorite band to the northwest and west; limited areas of siltstones and sandstones on the north and northeast side of the island (Bar Harbor Formation); and a highly deformed schist that is found on the north and west sides of the island (Ellsworth Schist) (Gilman and others, 1988). The fractured nature of these rocks allows limited amounts of ground water to accumulate and flow in the bedrock, providing ground-water-flow paths that may provide water to wetlands in low-lying areas of the island.

Maximum relief on the island is 475 m. Slopes are very steep in the rocky central mountains (fig. 1). These steep slopes and poorly permeable rocks make model simulations of the rocky central mountains difficult.

Base from U. S. Geological Survey
Digital line graph Bass Harbor (provisional, 1983), Bar Harbor (1982), Bartlett Island (1981), Seal Harbor (1983), Salsbury Cove (1981), and Southwest Harbor (1983), Maine, 1:24,000 quadrangles. Shaded relief from 10-m digital elevation model. Wetlands from U. S. Fish and Wildlife Service National Wetlands Inventory (1998)

Figure 1. Map of Mt. Desert Island, Maine, showing location of wetlands and Acadia National Park.

The water table in lower-elevation parts of the island (fig. 1) is in the surficial sediments, where those sediments are thick enough. In the higher-elevation parts of the island (and in lower-elevation parts of the island where the surficial sediments are very thin), the water table is in the fractured bedrock. On the basis of data from eight USGS monitoring wells and many homeowner wells, the water table is generally within 2 to 5 m of the land surface in the lower-relief parts of the island. Even at the top of Cadillac Mountain, the highest point on the island, the water table is only 18 m below land surface (unpublished well logs on file with the USGS in Augusta, Maine).

Recharge to the surficial sediments is through infiltration of precipitation. Recharge to the bedrock units is through direct infiltration of precipitation and runoff in areas where the surficial sediments are absent, and infiltration through the surficial sediments elsewhere. Potential amounts of recharge to the bedrock units for the northern part of the island are given in Nielsen (2002). Depending on slope, overburden, and rock type, the recharge to bedrock units is likely to be between 7.6 and 36 cm/year. Discharge of ground water occurs along the ocean boundary of the island, and to the many freshwater lakes, streams, and wetlands across the island.

Storage properties for the bedrock on Mt. Desert Island were investigated by Nielsen (2002). Geophysical surveys were used to estimate the fracture porosities of the Ellsworth Schist and the Shatter Zone, which ranged between 0.08 to 1.4 percent, and 0.1 to 0.7 percent, respectively. Fracture porosities of the other bedrock units were estimated from literature values. These estimates were: granite and other intrusive rocks, 0.002 to 1 percent; Bar Harbor Formation, 1 to 10 percent; and the Cranberry Island Volcanics, 3 to 10 percent. Estimates were not made for the surficial materials in that study, but textbook values of total porosities for some of these materials are: silts and clays, 35–70 percent; and sand and gravel, 25–50 percent (Freeze and Cherry, 1979). Porosities for southern New England tills composed of fragments of igneous and metamorphic rocks, such as are found on Mt. Desert Island, range from 4–41 percent (Melvin and others, 1992).

The hydraulic properties of the bedrock and surficial units are not well known. Previous studies on the Cranberry Island Volcanics suggest a hydraulic conductivity of 0.014 meters per day (m/d) (Paillet and Hanscomb, 2000). A ground-water-flow model of coastal New Hampshire, which includes several rock types similar to those on Mt. Desert Island, used hydraulic conductivities of 0.29 to 0.60 m/d for granites and other intrusive rocks (Mack and others, 2003). Some ground-water-flow model studies of granitic areas in Maine have estimated hydraulic conductivities to be from 0.02 to 0.12 m/d (Gerber and Hebson, 1996). Hydraulic conductivity values for metasandstones in Maine, which are analogous to the Bar Harbor Formation, have been estimated at 0.34 m/d (Gerber and Hebson, 1996). Hydraulic conductivity values for schists and phyllites, which are somewhat similar to the Ellsworth Schist, have been estimated as 0.06 to 1.09 m/d. The hydraulic conductivity of mixed fractured bedrock in the Hubbard Brook watershed of New Hampshire has been modeled at 0.012 m/d (Tiedeman and others, 1997). Somewhat more is known about the hydraulic conductivities of the surficial geologic units. The hydraulic conductivity of the Presumpscot Formation is on the order of 0.00001 m/d (Gerber and Hebson, 1996; Brainard and Hebson, 1996). Estimates of the hydraulic conductivity of till in northern New England range from 0.03 m/d (Gerber and Hebson, 1996) to 0.3 m/d (Mack, 2003). The hydraulic conductivity of peat is highly variable, and has not been reported for Maine. Green (1991) modeled ground-water flow in a Wisconsin wetland, which was similar to several of the large wetlands on Mt. Desert Island, and measured the hydraulic conductivity of peat there to be 0.046 m/d.

Discussion of Data Needed to Develop a Numerical Ground-Water-Flow Model

Discretization of the Hydrologic System

The majority of wetlands on Mt. Desert Island are on the northern and southwestern parts of the island, and it is in these areas that rural development adjacent to wetlands makes ground-water discharge of contaminants a concern. These areas could therefore be targeted for detailed ground-water-flow model development. Currently (2006), more water-level data and hydrogeologic data are available for these areas than for the higher-elevation mountainous central part of the island; accurate hydrogeologic information for an island-wide flow model does not currently exist.

With respect to addressing wetland issues, the ground-water-flow system on Mt. Desert Island could be discretized into a 3-layer model with a uniform 100-m grid spacing for the low-lying parts of the island. A smaller grid spacing would give more detail, but without more detailed input data (particularly geologic data), that level of detail would not significantly improve the accuracy of the model. The overall boundary of the model area could be a buffer around the island coastline extending 300–500 m into the ocean in some areas (fig. 2). In accordance with focusing on the northern and southern wetland-rich areas, the central mountainous areas could be set initially as an inactive part of the model (fig. 2), the boundaries of which would represent real geologic or hydrologic boundaries. The boundary between the southern active part of the model and the central mountainous area could correspond to the geologic transition between the shatter zone, the granites, and Cranberry Island Volcanics to the south (figs. 2 and 3), and could be modeled as a general head boundary. The boundary between the northern active part of the model could follow a topographic high west of Somes Sound (fig. 2), and could be modeled as a no-flow boundary. On the east, this boundary could follow a topographic high between Eagle Lake and the ocean to the east that could be modeled as a no-flow boundary. From Eagle Lake west to Somes Sound, the topographic high could be modeled as a general head boundary (fig. 2).

The top layer of the model could represent the unconsolidated sediments (where present), and the upper few meters of the bedrock where the unconsolidated sediments are absent (fig. 4). The top of layer 1 can be represented by the land surface. Geologic data from the Maine Geological Survey well drilling records can be used as input for the thickness of the surficial materials in the active parts of the model. At the edges of the model, the top layer could consist of constant-head cells in the ocean. Layer 2 could be a uniform 30-m or so in thickness, and could consist entirely of fractured bedrock. A layer 2 thickness of approximately 30 m is thick enough so that the water table would fall within either layer 1 or layer 2, but should not drop into layer 3. The top of layer 2 (bottom of layer 1) could represent the top of the bedrock (where the surficial sediments are present); the elevation of the top of layer 2 could vary depending on information about the depth to bedrock from well drilling records. Where surficial sediments are lacking and layer 1 is composed of bedrock (fig. 4), the thickness of layer 1, and therefore the elevation of the top of layer 2, would have to be arbitrarily chosen. Layer 3 would represent the deeper fractured bedrock, and could extend from the bottom of layer 2 to some set altitude below sea level, perhaps 500 m, to allow for deep circulation of ground water within the island. If a uniform thickness is used for layer 2, the elevation of the top of layer 3 (or any deeper layers) would vary with the elevation of the top of layer 2. The model could be further divided into additional layers, if computer resources allow and if more information on the vertical distribution of fractures or surficial geologic units becomes available.

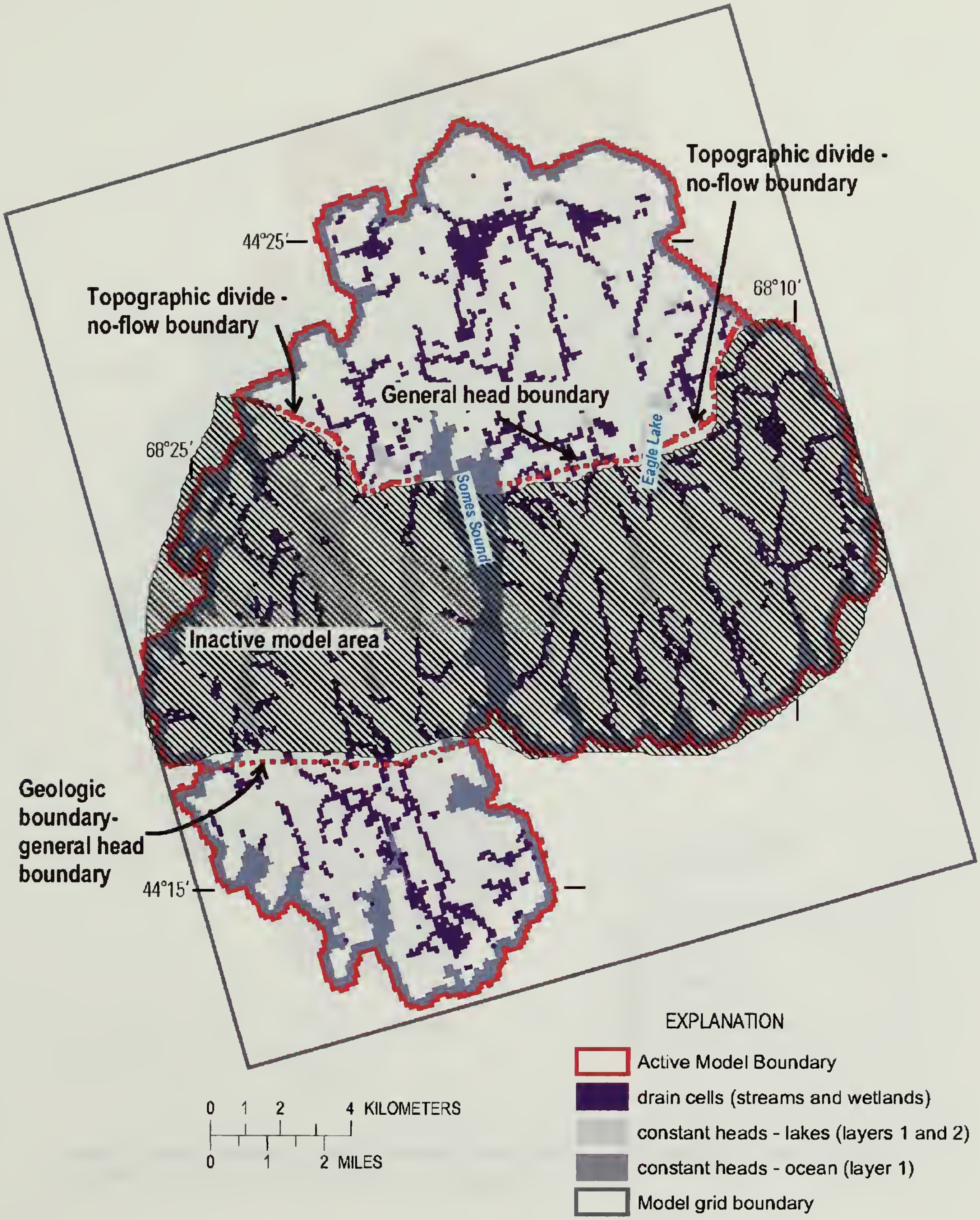

Figure 2. Suggestions for model area, boundary conditions, and locations of drain cells for possible ground-water-flow model of Mt. Desert Island, Maine

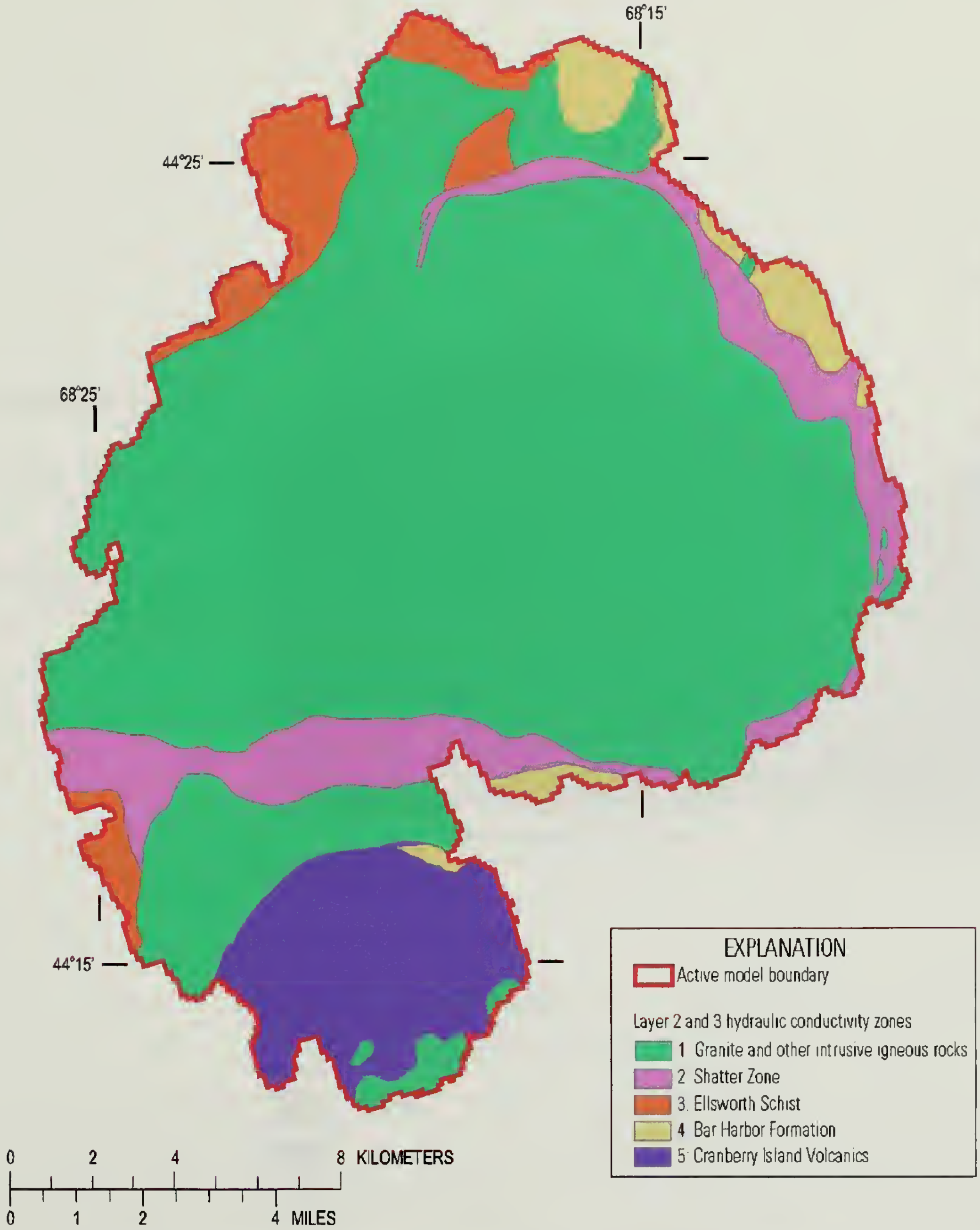

Figure 3. Possible distribution of hydraulic conductivity zones in bedrock layers of model (layers 2 and 3). Geology generalized from Gilman and Chapman, 1988 (Used with permission).

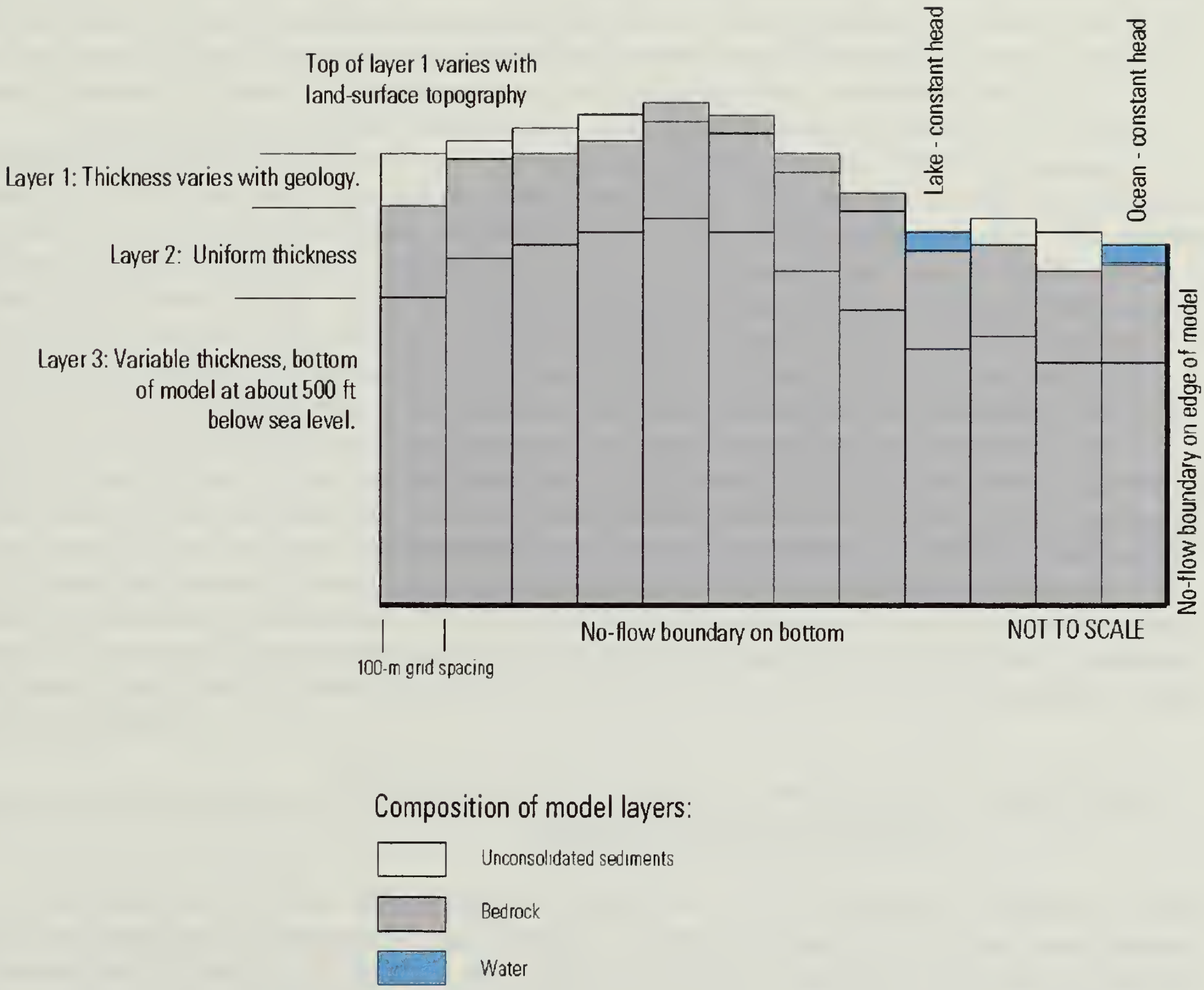

Figure 4. Possible layering scheme for ground-water-flow model for Mt. Desert Island, Maine.

To align the x- and y- directions of the model grid with the orientation of the topography of the island, major valleys, and strike of lineations (fig. 1), the 100-m grid could be rotated 16 degrees to the west (fig. 2). This could help reduce the effect of horizontal anisotropy in the bedrock units.

Boundary Conditions

The saltwater interface at the edge of the island could be modeled as a constant-head boundary in layer 1 (ocean areas, fig. 4). Although in reality saltwater is denser than fresh water, and an equivalent freshwater head at the bottom of the ocean (where ground-water discharge occurs) would be somewhat higher than sea level, the cells representing the ocean could be given a constant head of zero, for simplification. Large lakes also could be modeled as constant heads, with the lake water-surface elevation set as the modeled constant head. The bottom of layer 3 and the lateral boundaries of layers 1, 2 and 3 could be modeled as no-flow boundaries (see fig. 4).

Two methods of specifically simulating ground-water discharge to streams and rivers are available in MODFLOW-2000—the river package and the drain package. The river package simulates ground-water discharge to a river and ground-water recharge from a river, depending on the relative water levels in the aquifer and the river. The drain package simulates only ground-water discharge to the river or stream; this package would be a more appropriate choice for the small streams on Mt. Desert Island, which are often on steep slopes and do not have much opportunity to provide flow back into the ground-water system. The drain package is also useful for simulating wetlands: thus, streams and wetlands on the island could be simulated with it. Using the drain package, ground-water discharge is determined by the head in an aquifer cell containing a stream segment, the altitude of that stream segment, and the conductance of the stream bottom. The altitude of each stream segment can be determined as the average altitude of the stream segment within each grid cell, as determined from a 10-m digital elevation model. Because of the steepness of the topography on the island, the calculated stream-segment altitude may fall below the bottom of the model cell in layer 1 in which it resides. In that case, the bottom altitude of the stream segment would be set to the bottom of the model cell. The conductance of the stream bottom is the product of the length of the stream segment in the model cell multiplied by the width of the stream multiplied by the hydraulic conductivity of the streambed sediment, divided by the thickness of the riverbed sediments:

$$\text{Stream bottom conductance} = \frac{[\text{stream length} * \text{stream width} * \text{streambed sediment conductivity}]}{\text{thickness of streambed sediments}}$$

The length of the stream segment in each model cell could be determined using the 1:24,000 digital line graph data for streams for each USGS 7.5-minute quadrangle in the study area. Because the streams on the island are all small, a unit width of 1 m could be assigned to all stream segments, and an arbitrary uniform thickness of 5 centimeters (cm) could be used for the thickness of the streambed sediments. The hydraulic conductivity of the streambed sediments in each cell could be estimated from the Natural Resources Conservation Service (NRCS) soils maps (Jordan, 1998), which may be obtained as GIS coverages from the Maine Office of Geographic Information Systems (2004). Soil units could be grouped into 10 groups based on the textural and compositional descriptions of each (table 1). Hydraulic conductivities of each soil group, which can be used to calculate drain conductances, were estimated from literature values for those sediment types in New England (Green, 1991; Gerber and Hebson, 1996; Brainard and Hebson, 1996; Mack and others, 2003; Freeze and Cherry, 1979) (table 1).

Table 1. Hydraulic conductivities that could be used for drain conductances.

[See figure 2 for possible drain cell locations; m/d, meters per day; cm, centimeters; >, greater than]

Soil/Surficial material type	Estimated hydraulic conductivity for drain conductances, in m/d
Artificial fill	0
Clay and silt/clay	0.00003
Gravelly soils, thick (> 60 cm)	10
Mixed soil types, thick (> 60 cm)	.3
Peat over till	.05
Peat over clay	.00003
Sand and gravel > 30 cm thick	10
Sandy soils, thin (< 30 cm)	.3
Bare rock and soils < 15 cm thick	10
Till, all thicknesses	.15

The distribution of wetlands could be determined from the National Wetland Inventory maps (U.S. Fish and Wildlife Service, 1998). Wetlands smaller than two model cells (20,000 square meters, or 2 hectares) may not be large enough to simulate effectively, unless a grid size smaller than 100 m is used. The discharge of ground water to wetlands could be determined using the same equation as for stream drains, except that the area would be calculated as the entire area of the model cell containing the wetland (100 m × 100 m), the altitude of the wetland drain would be the land surface, and the conductance of the bottom sediments would be the hydraulic conductivity of the underlying soil below the wetland (as mapped on the NRCS maps) multiplied by the area of the model cell, divided by the thickness of the underlying sediments:

$$\text{Wetland bottom conductance} = \frac{[\text{hydraulic conductivity of sediments under wetland} * \text{area of wetland cell}]}{\text{thickness of sediments under wetland}}$$

Drain parameters for model cells that have wetlands and a stream could be determined from the wetland data, which may supersede the stream data because more discharge would likely take place from a large wetland than a small stream. A possible distribution of drain cells in the model is shown in figure 2.

Aquifer-System Properties

The surficial geologic units in layer 1 could be separated into as many as 8 hydraulic-conductivity zones, based on the surficial geologic map of the island (Gilman and others, 1988) supplemented by soil texture information in the NRCS soil survey (Jordan, 1998). These potential zones could include: coarse-grained units (sand and gravel), thick till (thicker than 2 m), thin till (thinner than 2 m), peat, Presumpscot Formation silt and clay, undifferentiated marine sediments that are probably clay based on soil texture data (Jordan, 1998), water (surface-water bodies), and bare bedrock. Figure 5 shows the distribution of surficial geologic units that could be used to determine hydraulic conductivities in a potential model. If surficial geologic mapping data become available at a larger scale than the existing map (which is at 1:50,000), it would be desirable to use the more detailed data.

The distribution of initial hydraulic conductivity zones in the bedrock layers could be taken from the bedrock geology map of Mt. Desert Island (Gilman and others, 1988), unless more detailed geologic mapping becomes available. The bedrock units described earlier could be divided into five hydraulic-conductivity zones for layers 2 and 3: one each for (1) the granite and other intrusive rocks, (2) the Bar Harbor Formation, (3) the Cranberry Island Volcanics, (4) the Ellsworth Schist, and (5) the Shatter Zone. The distribution of units could be the same in both layers, as no information is available on the vertical variation of the geologic units. Five suggested hydraulic conductivity zones for layers 2 and 3 are shown in figure 3. Any additional information on the distribution of hydraulic properties within these units from fracture mapping, well yield data, or other sources could be very useful to further subdivide the hydraulic conductivity zones.

Hydraulic conductivity values in a ground-water-flow model are often adjusted during the calibration process. Adjustments are done using an initial value of hydraulic conductivity that is based on existing information for each geologic unit, and the hydraulic conductivity values typically are varied within a set range to obtain a satisfactory match between known and modeled heads and water fluxes. Initial values and possible ranges of hydraulic conductivity values for each of the geologic units that could be used in a model are given in table 2, which lists the surficial units (layer 1) and the bedrock units (layers 2 and 3). Ranges and initial values shown for the hydraulic conductivities are primarily based on the published literature on ground-water-flow models in Maine and elsewhere in New England (Tiedeman and others, 1998; Hebson, 1996; Paillet and Hanscomb, 2000; Mack and others, 2003; Gerber and Hebson, 1996, and Green, 1991). Ranges for the Presumpscot Formation (sometimes mapped as clayey marine sediments) are large because if the unit is fractured, the hydraulic conductivity may be greatly enhanced (Gerber and Hebson, 1996).

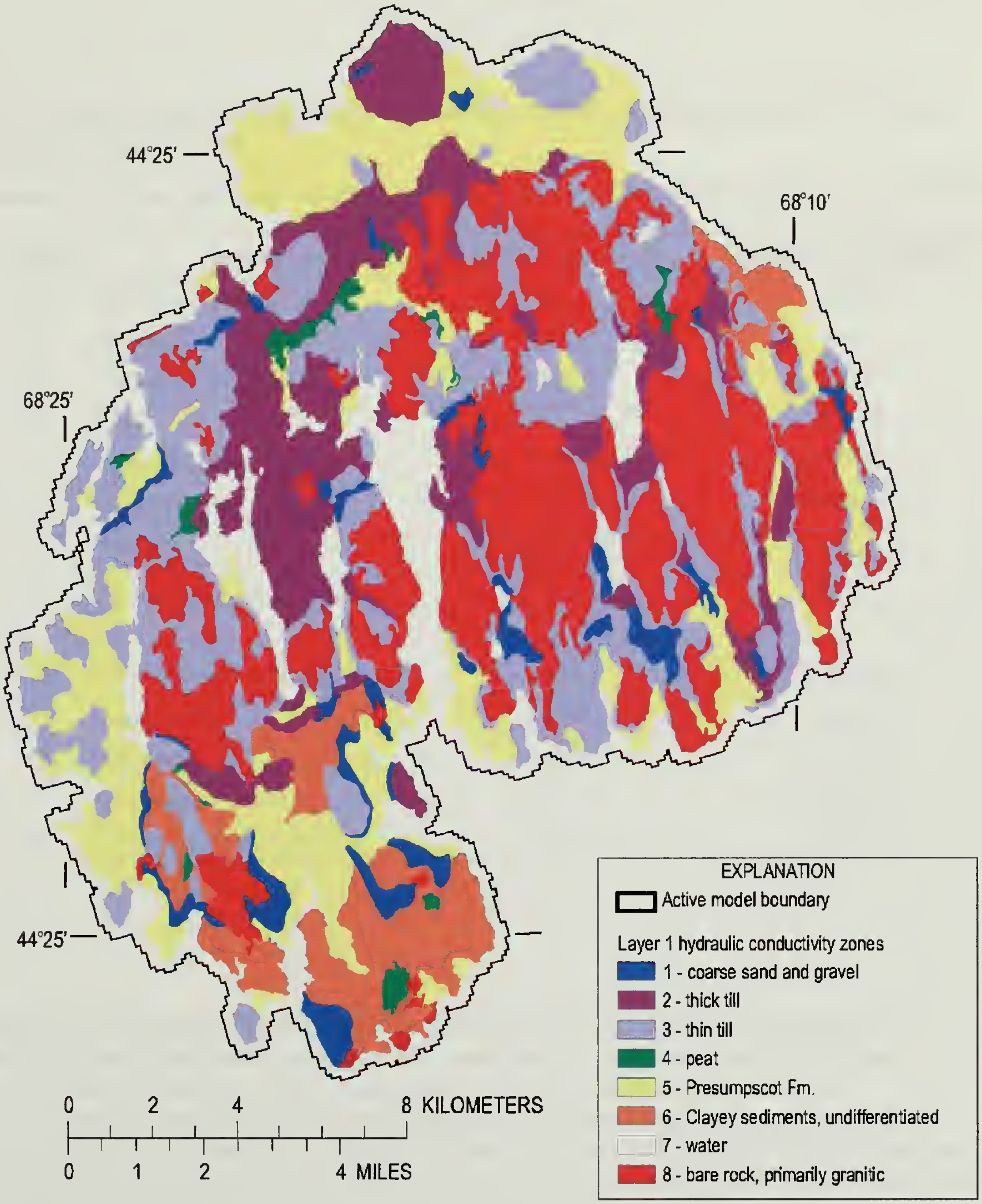

Figure 5. Possible distribution of hydraulic conductivity zones in surficial materials (layer 1), based on surficial geologic map by Lowell and Borns, 1988 (Used with permission).

Table 2. Initial hydraulic conductivity values that could be used in a ground-water-flow model, based on references listed in text.

[For spatial distribution of zones see figures 3 and 5; K, hydraulic conductivity; m/d, meters per day; --, not applicable]

Layer	Zone	Geologic unit	Initial K value (m/d)	Possible range in K (m/d)
1	1	Coarse sand and gravel	10	0.3–30
	2	Thick till	0.3	0.1–5
	3	Thin till	0.2	0.1–5
	4	Peat	5	0.1–10
	5	Presumpscot formation	0.00003	0.00001–0.01
	6	Clayey marine sediments	0.0005	0.00001–0.01
	7	Water	10,000 (arbitrary high value)	--
	8	Bare rock, primarily granitic	0.02	0.005–1.0
2 and 3	1	Granite/intrusive igneous rocks	0.02	0.005–1.0
	2	Shatter zone	0.03	.01–0.5
	3	Ellsworth schist	0.03	.01–1.0
	4	Bar Harbor formation	0.3	0.1–2.0
	5	Cranberry Island volcanics	0.08	.01–1.0

Stresses

Recharge to the bedrock aquifer in the northern part of the island, corresponding to the suggested northern active model area, has been estimated to range between 0.0002 and 0.001 m/d (3 to 15 in/yr, Nielsen, 2002), depending on soil type. The larger amount is approximately 25 percent of the incoming precipitation (150 centimeters per year (cm/yr), or 0.0042 m/d). The soils distribution from NRCS (Jordan, 1988, scale 1:20:000) could be assigned to a surficial sediment type based on the soil unit textural descriptions. Each surficial sediment type could be assigned a recharge rate, which is represented as a percentage of transmission of incoming precipitation (table 3). These percentages were estimated based on reports by Tiedeman and others (1998), Gerber and Hebson (1996), and by the previous work on Mt. Desert Island by Nielsen (2002). The study by Nielsen (2002) did not include coarse sand and gravel deposits or peat, which are estimated to have a recharge rate greater than 25 percent of the incoming precipitation. A very low recharge rate could be applied to open-water areas because they are constant-head zones where recharge does not matter.

Table 3. Estimated recharge rates for surficial geologic units.

Layer 1 zone – geologic description	Fraction of total precipitation becoming recharge
1 -- coarse sand and gravel	0.40
2 -- thick till	.25
3 -- thin till	.20
4 -- wetlands (peat)	.30
5 -- clay	.05
6 -- other fine-grained sediments	.05
7 – open water	.01
10 -- bare rock	.20–.25

Calibration Targets

Calibration targets for a ground-water-flow model should include measurements of water levels in the modeled aquifers, and of stream discharge. As of this report (2006), water levels have been measured in 39 wells across the island, exclusively in the bedrock units. Many of these water levels could be used as calibration targets for the model. Low-flow stream discharge has been measured in 25 river basins, which represent over 50 percent of the land area of the island. These water-level and streamflow measurements are on file at the U.S. Geological Survey office in Augusta, Maine. The low-flow stream-discharge measurements could be compared to continuous-record streamflow data in several small coastal rivers in Maine to estimate average base-flow discharge, which could be compared to modeled stream and wetland drain flows. In the summer of 2006, a new continuous-record streamflow gaging station was established on Otter Creek, in the southeast part of the island, as part of the National Park Service's New England Temperate Network monitoring program (Lombard and others, 2006). Once data have been collected for several years, this station will be useful in providing calibration targets for streamflow on Mt. Desert Island. No water-level measurements are currently (2006) available in the surficial materials to use as calibration targets for a model; if a ground-water model is planned, it would be useful to obtain water-level measurements in shallow wells in the surficial materials around the island.

Need for Additional Data

Although data for Mt. Desert Island may exist that are sufficient to construct a highly generalized ground-water-flow model for parts of the island, these data are not detailed enough to answer questions about water flow in and around wetlands on the island, or to predict the movement of possible ground-water contamination as it relates to the locations of wetlands or other water bodies. Additional data would be needed to accurately construct and calibrate a ground-water-flow model for Mt. Desert Island, whether the whole island or just parts of the island are modeled. Additional data needed for such a model would include: more detailed information on the distribution and thickness of the Presumpscot Formation and other surficial geologic units; water-level data in shallow wells in the surficial geologic units and in bedrock units; data from nested wells that show vertical hydraulic gradients within the bedrock and between the bedrock and the

surficial units; detailed geologic mapping (both bedrock and surficial) at a scale of 1:24,000; additional information on the hydraulic conductivities of the various geologic units (bedrock and surficial materials); and information on direction and magnitude of anisotropy in the bedrock units.

References

Brainard, E.C., and Hebson, C.S., 1996, Hydrogeology of Presumpscot Clay-Silt using isotopes, *in* Loiselle, M., Weddle, T.K., and White, C., eds., 1996, Selected papers on the Hydrogeology of Maine: Augusta, Maine, Maine Geological Survey, Bulletin 4, 143 p.

Caswell, W.B., and Lanctot, E.M., 1977, Ground water resource maps of southern Hancock County: Augusta, Maine, Maine Geological Survey, Department of Conservation, Division of Hydrogeology, 2 p., 4 plates.

Chapman, C.A., and Rioux, R.L., 1958, Statistical study of topography, sheeting, and jointing in granite, Acadia National Park: American Journal of Science, v. 256, p. 111–127.

Freeze, R.A., and Cherry, J.A., 1979, Groundwater: Englewood Cliffs, N.J., Prentice-Hall, Inc., 604 p.

Gerber, R.G., and Hebson, C.S., 1996, Ground water recharge rates for Maine soils and bedrock, *in* Loiselle, M., Weddle, T.K., and White, C., eds., 1996, Selected papers on the Hydrogeology of Maine: Augusta, Maine, Maine Geological Survey, Bulletin 4, 143 p.

Gilman, R.A., and Chapman, C.A., 1988, Bedrock geology of Mount Desert Island, *in* Gilman, R.A., Chapman, C.A., Lowell, T.V., and Borns, H.W., Jr., 1988, The Geology of Mount Desert Island, A visitor's guide to the geology of Acadia National Park: Maine Geological Survey Bulletin 38, 50 p., 2 plates.

Gilman, R.A., Chapman, C.A., Lowell, T.V., and Borns, H.W., Jr., 1988, The Geology of Mount Desert Island, A visitor's guide to the geology of Acadia National Park: Maine Geological Survey Bulletin 38, 50 p., 2 plates.

Green, M.C., 1991, Modeling wetland groundwater flow and predicting hydrologic response to management alternatives at Summerton Bog, Oxford, Wisconsin: Madison, Wis., University of Wisconsin-Madison Master's Thesis, 123 p., 5 appendixes.

Harbaugh, A.W., Banta, E.R., Hill, M.C., and McDonald, M.G., 2000, Modflow-2000, the U.S. Geological Survey modular ground-water model—User guide to modularization concepts and the ground-water flow process: U.S. Geological Survey Open-File Report 00–92, 121 p.

Jordan, G.B., 1998, Soil survey of Hancock County area, Maine: U.S. Department of Agriculture, Natural Resources Conservation Service, 278 p., 103 map sheets. Vector digital data from Maine Office of Geographic Information Systems, scale 1:20,000, accessed online January 2004 at *http://apollo.ogis.state.me.us/catalog/catalog.asp?state=2&extent=county*

Lombard, P.J., Gawley, W.G., and Caldwell, J.M., 2006, Freshwater Vital-Signs Monitoring Plan for National Parks in the Northeast Temperate Network (NETN) PHASE III: Water-Quality Monitoring Protocols in Lakes, Ponds and Streams: U.S. Geological Survey Administrative Report, 143 p.

Lowell, T.V., 1989, Late Wisconsin glacial geology of the eastern portion of Mount Desert Island, *in* Tucker, R.D., and Marvinney, R.G., eds., 1989, Studies in Maine Geology Volume 6—Quaternary Geology: Augusta, Maine, Maine Geological Survey, p. 103–118.

Lowell, T.V. and Borns, H.W., 1988, Surficial geology of Mount Desert Island, *in* Gilman, R.A., Chapman, C.A., Lowell, T.V., and Borns, H.W., Jr., 1988, The Geology of Mount Desert Island, A visitor's guide to the geology of Acadia National Park: Maine Geological Survey Bulletin 38, 50 p., 2 plates.

Maine Office of Geographic Information Systems, 2004, Natural Resources Conservation Service vector digital data for Hancock County, Maine, scale 1:20,000, accessed online January 2004 at *http://apollo.ogis.state.me.us/catalog/catalog.asp?state=2&extent=county.*

McDonald, M.G., and Harbaugh, A.W., 1988, A modular three-dimensional finite-difference ground-water flow model: U.S. Geological Survey Techniques of Water-Resources Investigations, book 6, chap. A1, 14 chapters, variably paginated, 5 appendixes.

Mack, T.J., 2003, Preliminary ground-water-flow model of a coastal bedrock-aquifer system, Southeastern New Hampshire, *in* MODFLOW and More 2003: Understanding through Modeling, Denver, Colo., September 17–19, 2003, Abstracts with Programs: International Ground Water Modeling Center, p. 639–643.

Melvin, R.L., de Lima, V.A., and Stone, B.D., 1992, The stratigraphy and hydraulic properties of tills in Southern New England: U.S. Geological Survey Open-File Report 91–481, 53 p.

Nielsen, M.G., 2002, Estimated quantity of water in fractured bedrock units on Mt. Desert Island, and estimated ground-water use, recharge, and dilution of nitrogen in septic waste in the Bar Harbor area, Maine: U.S. Geological Survey Open-File Report 02–435, 45 p.

Paillet, F.L., and Hanscomb, H., 2000, Borehole geophysical characterization of hydraulic stimulation of fractured bedrock aquifers, *in* Powers, M.H., Ibrahim, A.B., and Cramer, Lynn, comps. and eds., Proceedings of the Symposium on the Application of Geophysics to Engineering and Environmental Problems, February 20–24, 2000: Wheat Ridge, Colo., Environmental and Engineering Geophysical Society, p. 567–576.

Smith, G.W., 1985, Chronology of Late Wisconsinan deglaciation of coastal Maine, *in* Borns, H.W., Jr., LaSalle, P., and Thompson, W.B., eds., 1985, Late Pleistocene history of northeastern New England and adjacent Quebec: Boulder, Colorado, Geological Society of America, Geological Society of America Special Paper 197, p. 29–44.

Tiedeman, C.R., Goode, D.J., and Hsieh, P.A., 1997, Numerical simulation of ground-water flow through glacial deposits and crystalline bedrock in the Mirror Lake area, Grafton County, New Hampshire: U.S. Geological Survey Professional Paper 1572, 50 p.

U.S. Fish and Wildlife Service, 1998, National Wetlands Inventory Maps, vector digital data from Maine Office of Geographic Information Systems, scale 1:24,000. Accessed online on January 3, 2000 at http://megis.maine.gov/catalog/.